ADVANCED REACTOR SAFEGUARDS

NDA Measurement Campaigns

PRESENTED BY

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OAK RIDGE National Laboratory

INL Idaho National Laboratory

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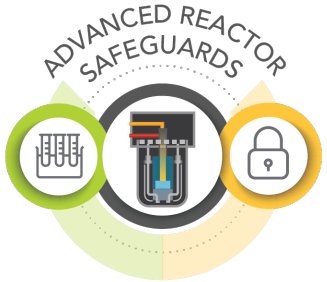
U.S. DEPARTMENT OF ENERGY

Objectives



- Enable maximum use of rapid, cost-effective nondestructive assay (NDA) to meet safeguards requirements for advanced reactors
- Directly measure NDA uncertainty to provide a comprehensive set of validated measurement capabilities for safeguards models
- Current focus is extending measurements to TRISO fuels

Previous project highlights

FY20: Gamma measurement campaign at LANL

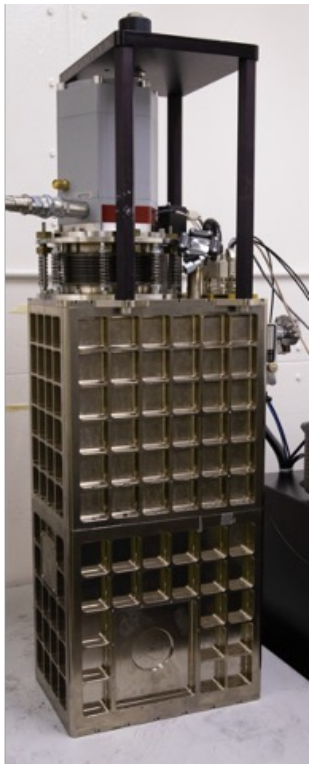
- Irradiated fuel and separation process samples received from Argonne
- Direct comparison of performance between high-purity germanium and microcalorimeter gamma spectrometers

FY21: Neutron measurement campaign at ORNL

- Irradiated fuel rod sections measured at IFEL hot cell
- Process monitoring signatures demonstrated
- Direct comparison of performance between miniHDND, ^{3}He, and fission chamber neutron detectors

ORNL FY22-23 results to date: gamma signatures of fuel burnup and low-Z matrices

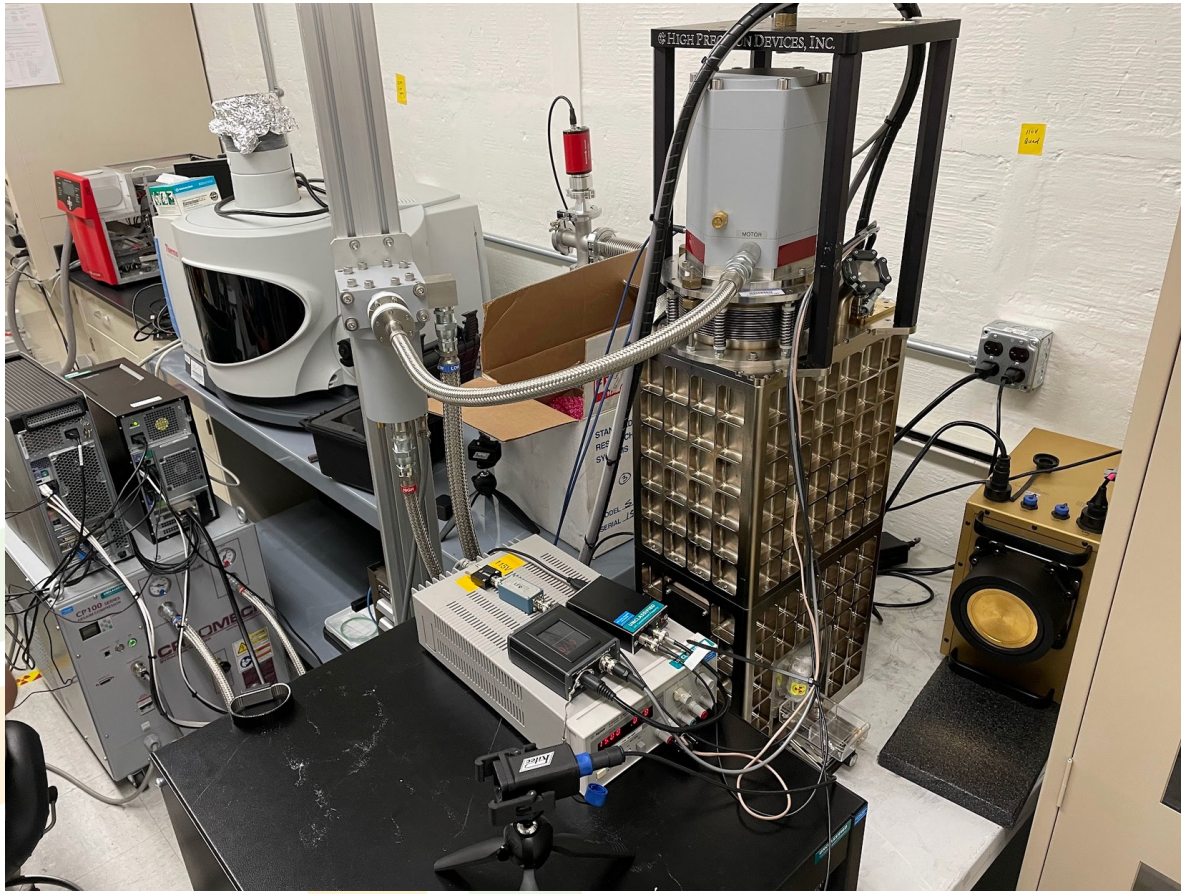
Type	Model	Detection Volume	FWHM at 123 keV	FWHM at 662 keV
CZT	Ritec µSPEC500	500 mm^3 quasi hemispherical CZT	4.9-5.3 keV	8.1-8.4 keV
HPGe	Ortec IDM-200-P	85 mm diameter x 30 mm length P-type HPGe	1.63-1.70 keV	2.02-2.12 keV
HPGe	Canberra GC2518	62 mm diameter x 35.5 mm HPGe	1.03-1.07 keV	1.45-1.47 keV
microcalorimeter	SOFIA	256 superconducting transition-edge sensors	0.06-0.11 keV	(outside of energy range)

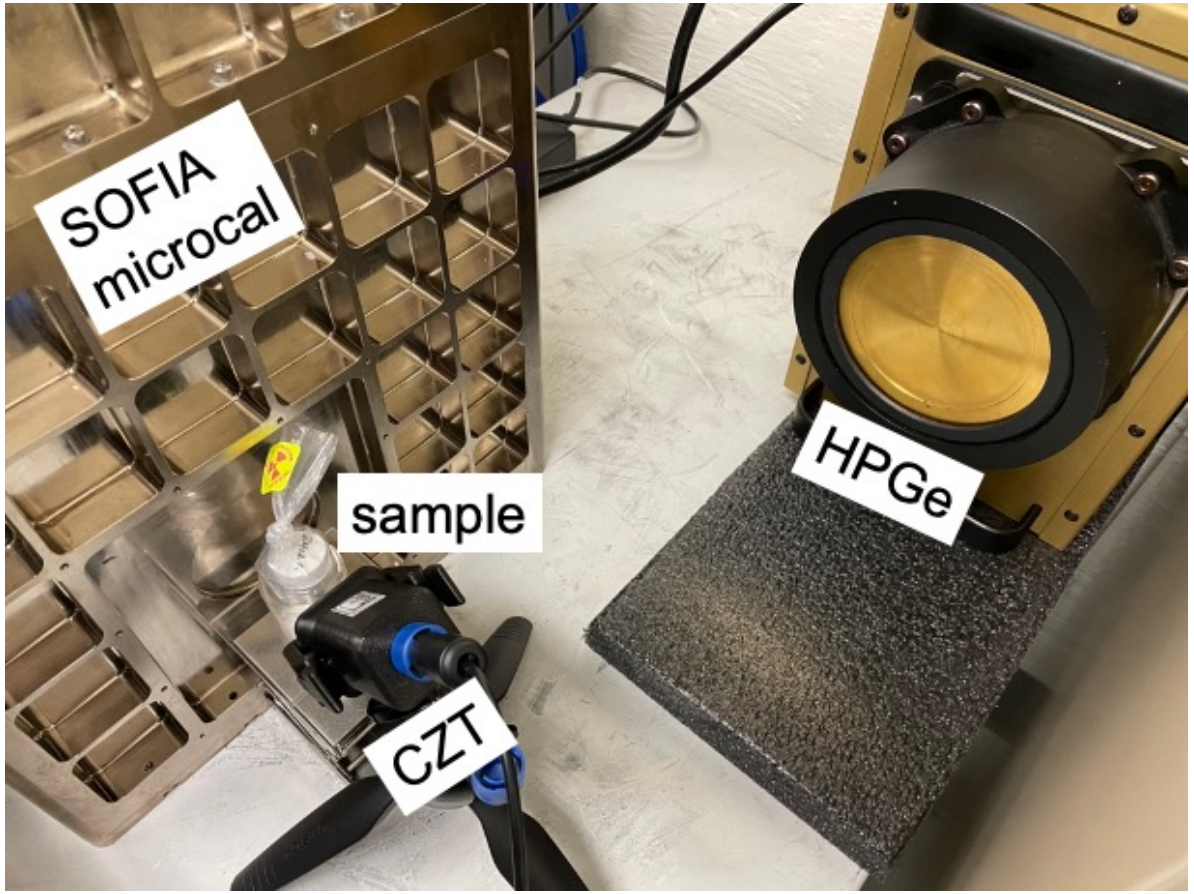


Dissolved LWR fuels selected to represent a range of burnup and cooling time

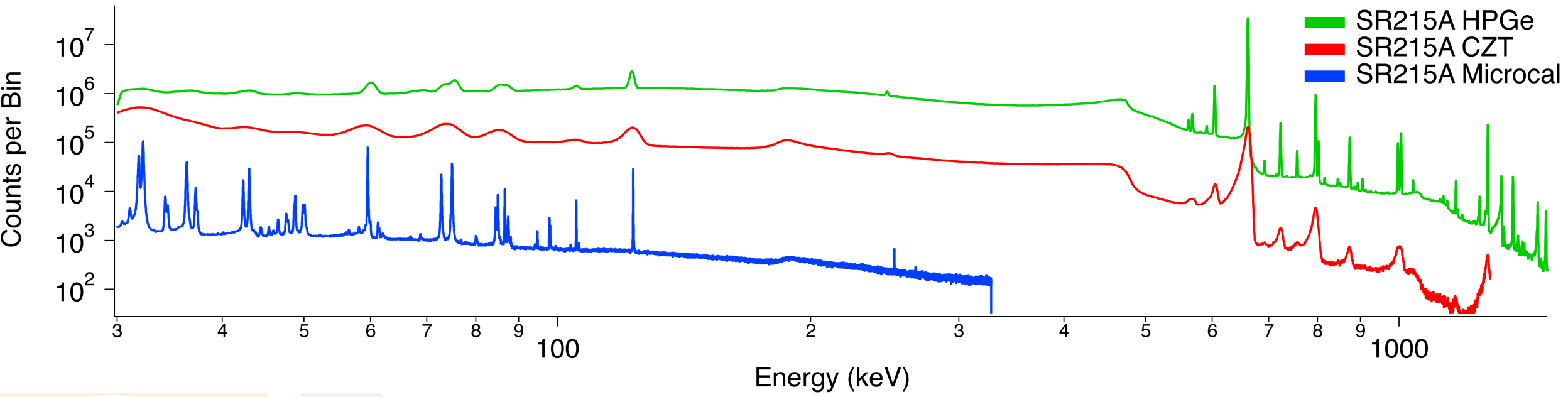
Sample ID	Burnup (GWd/MTU)	Discharge Date (year)	Solution Mass (g)	Gamma Dose Rate(mrem/hr)	Beta Dose Rate (mrad/hr)
SR-35-2402A	65.5	1989	0.4222	16	2628
SR-1450C	65.4	2000	0.3456	18	2619
SR-215A	46.9	2010	0.2502	22	3501
SR-240A	44.7	1994	0.3754	16	3528
SR-0165A	38.8	1994	0.4375	20	3570
124240	Gamma standard solution containing Pb-210, Am-241, Cd-109, Co-57, Ce-139, Hg-203, Sn-113, Sr-85, Cs-137, Y-88, Co-60				

Simultaneous measurements

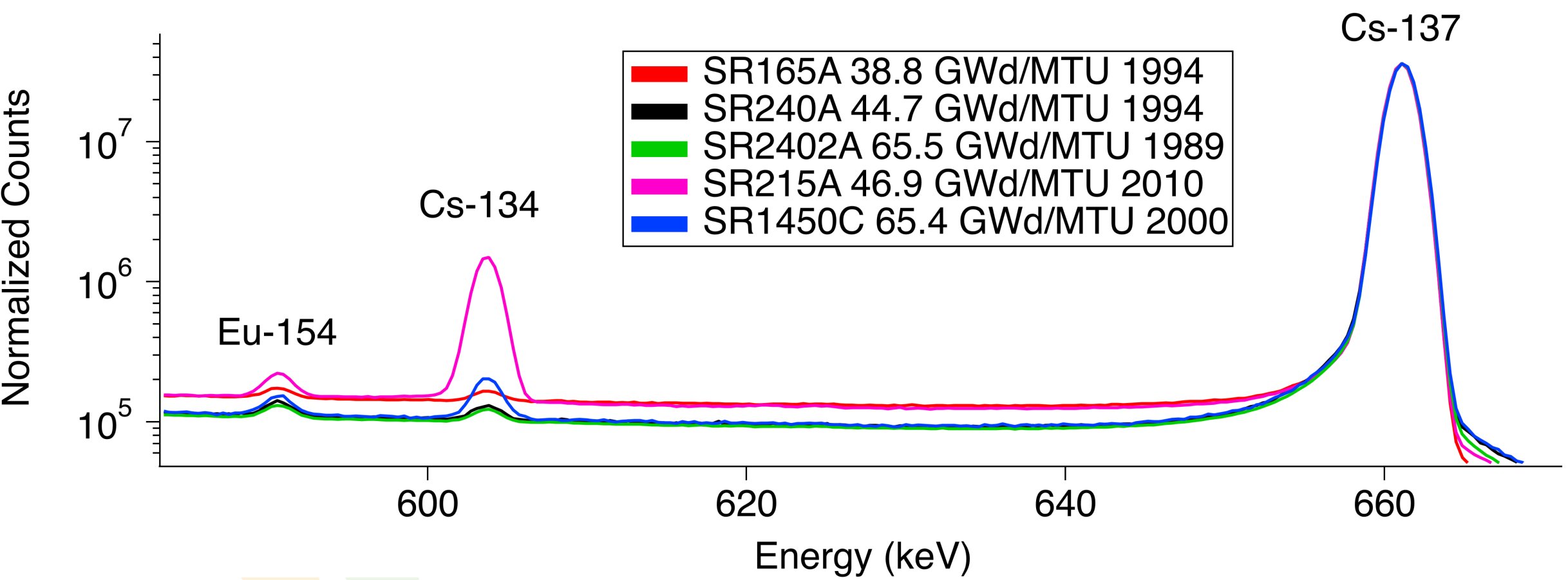




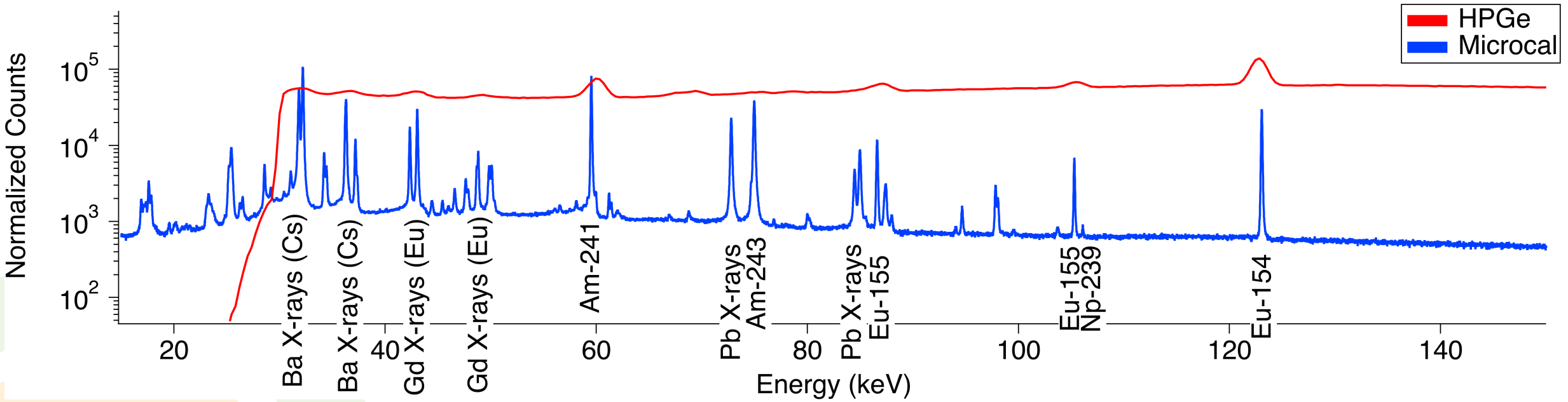
Complementary information is available from different detector types



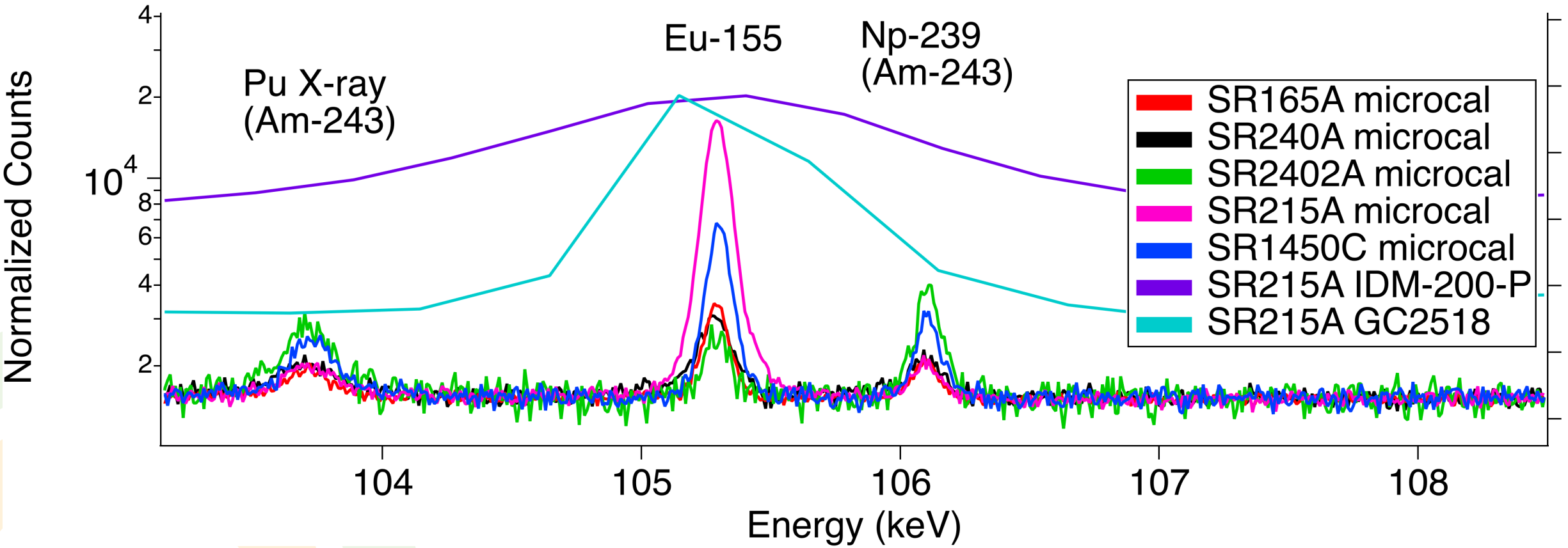
$^{134}Cs/^{137}Cs$ measured with HPGe



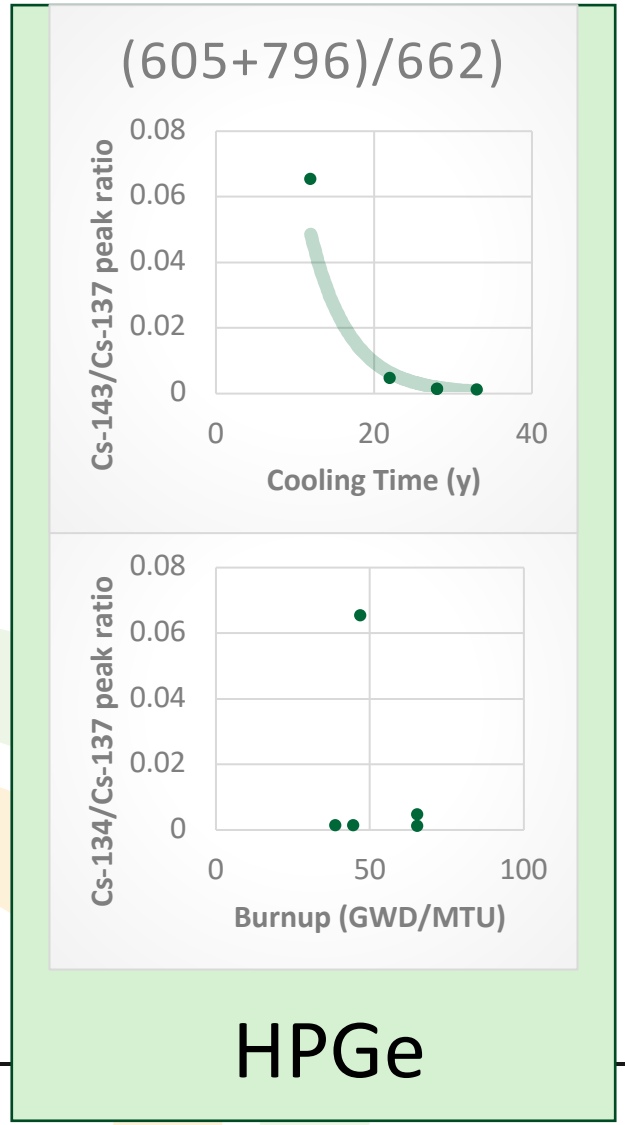
Low-energy signatures



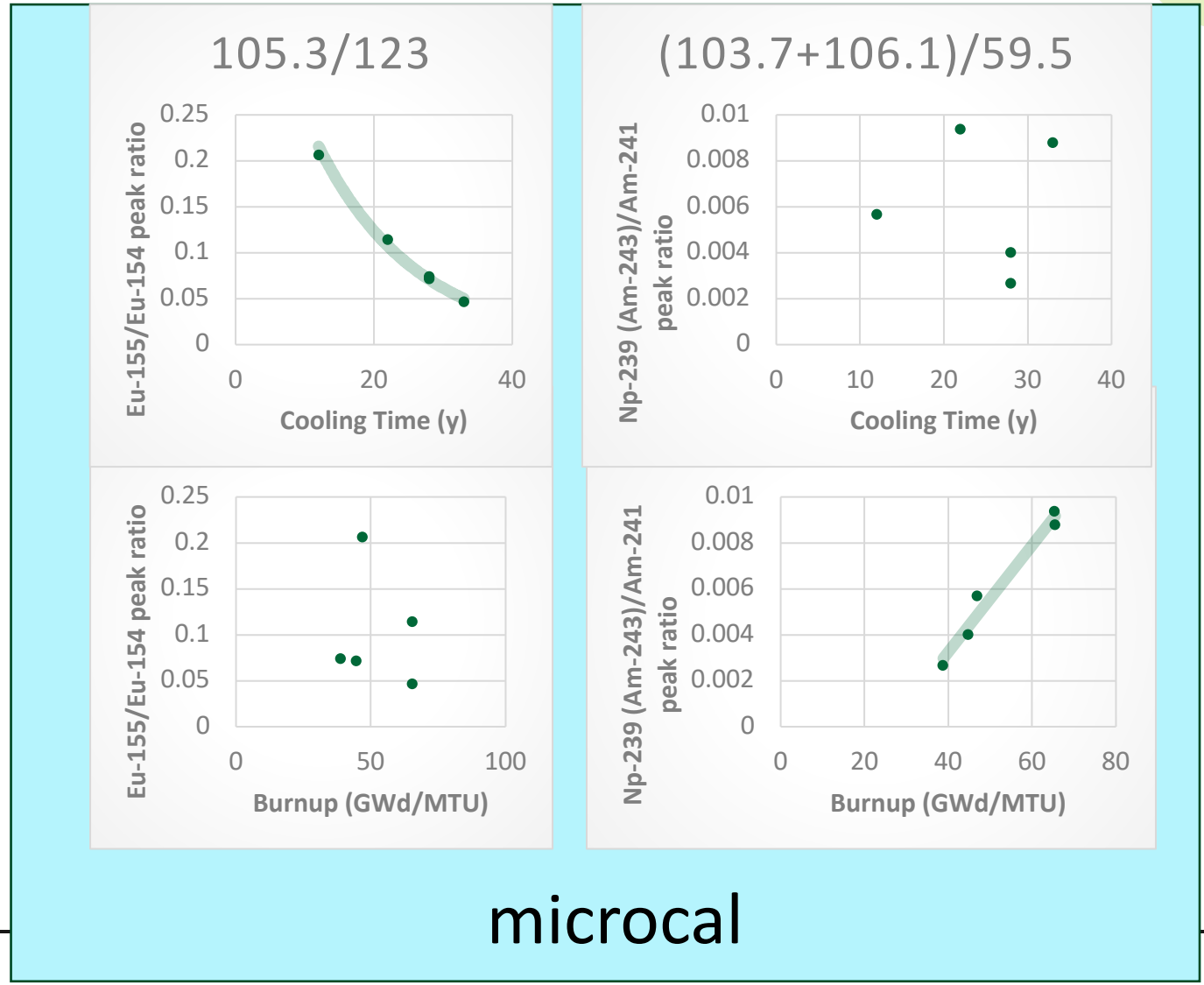
Low-energy signatures



Additional ratios can help to separate effects of burnup and irradiation timeline

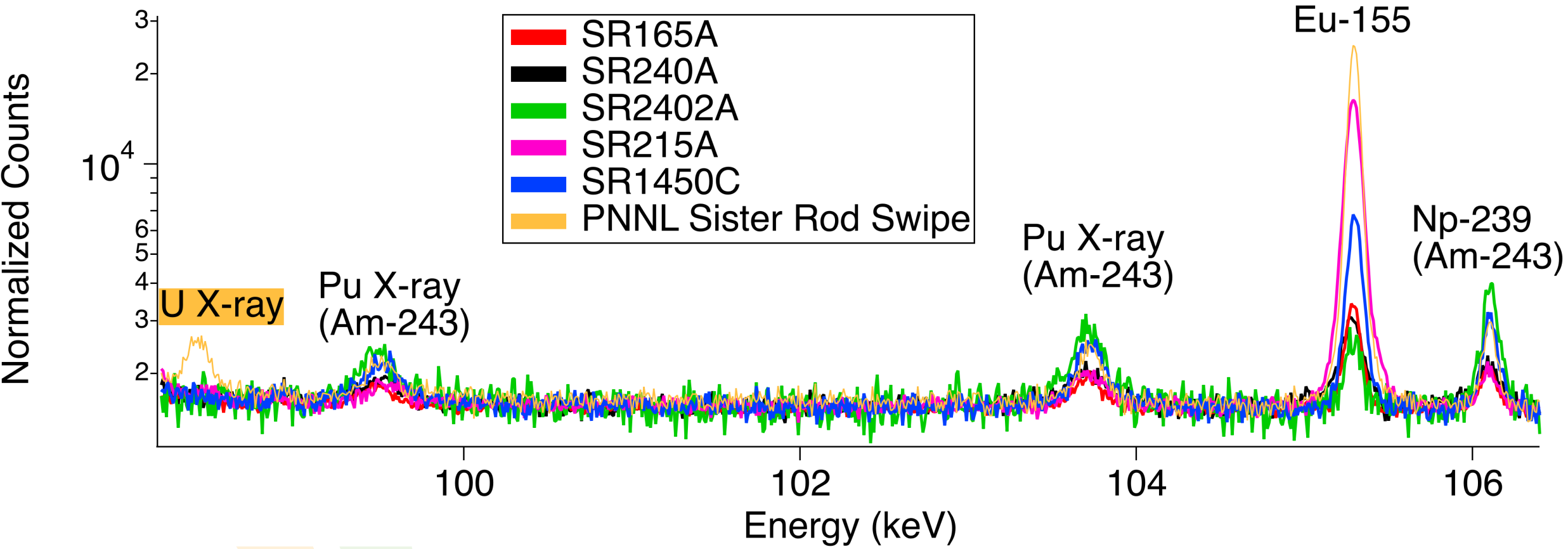


HPGe



microcal

Solid vs. liquid fuels



Irradiated TRISO measurements

- AGR compacts available at Irradiated Fuel Examination Facility
- Single particles in second floor hot cells
- Larger pieces and intact compacts in first floor hot cells

Table 10. As-irradiated compacts subjected to DLBL and IMGA.

Compact	Kernel	Temperature (°C) [a]			Burnup [b] (% FIMA)	Fast Fluence [b] (10^{25} n/m^2)
		TAVA	TA_{min}	TA_{max}		
3-1-2	UO_2	1012	903	1084	10.66	3.45
3-3-1	UO_2	1062	997	1104	10.46	3.49
2-2-1	UCO	1287	1185	1353	12.47	3.35
2-2-3	UCO	1261	1161	1335	10.80	2.99
5-2-3	UCO	1108	1003	1184	10.42	3.00
5-3-3	UCO	1093	986	1172	10.07	2.91
5-4-2	UCO	1071	927	1168	12.03	3.14
6-2-3	UCO	1095	1012	1157	8.22	2.30
6-3-3	UCO	1060	970	1134	7.46	2.14
6-4-1	UCO	1018	891	1106	9.24	2.20

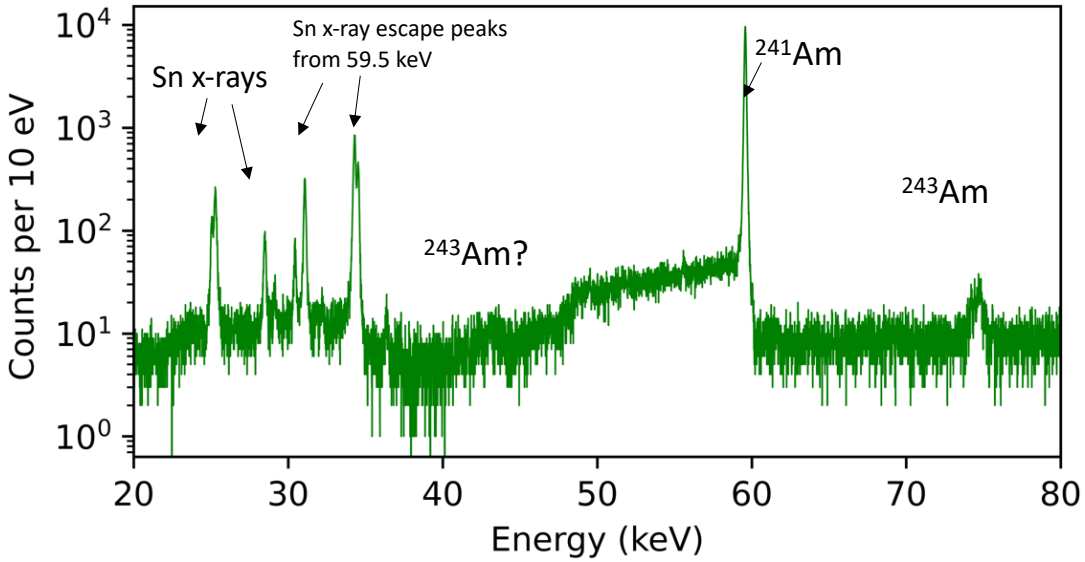
a. Hawkes 2014a.
b. Sterbentz 2014.

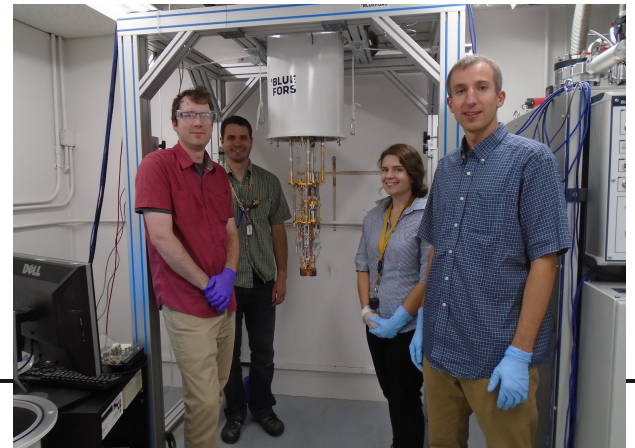
Planned location
(photo of FY21 neutron measurements)

From INL/EXT-21-64279

INL measurement campaign

- Microcalorimeter spectrometer now commissioned at Analytical Laboratory through MPACT
- Single TRISO particles or dissolved TRISO fuel with additional irradiation parameters
- Emphasis on freshly irradiated materials from AGR





Summary

- Completed measurements of dissolved LWR fuel burnup series
  - $^{154/155}$Eu and $^{241/243}$Am can complement $^{134/137}$Cs for better burnup and irradiation history characterization
- Irradiated TRISO fuel measurements planned for May and June